SmartPilots
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European Union
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VTT pilot plants for bio and circular economy

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SmartPilots study visit, 24.5.2017

Solutions for Natural Resources and Environment

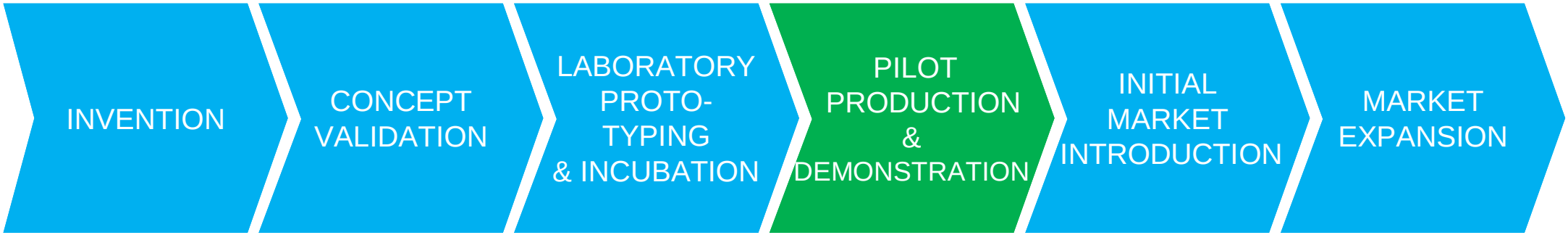
VTT Technical Research Centre of Finland Ltd

Contents

- VTT pilot plants for bio- and circular economy
- Bioruukki pilot centre
- Operation and Business models
- Funding of the pilot investments and operations
- Impact and co-operations

VTT pilot plants for bio- and circular economy

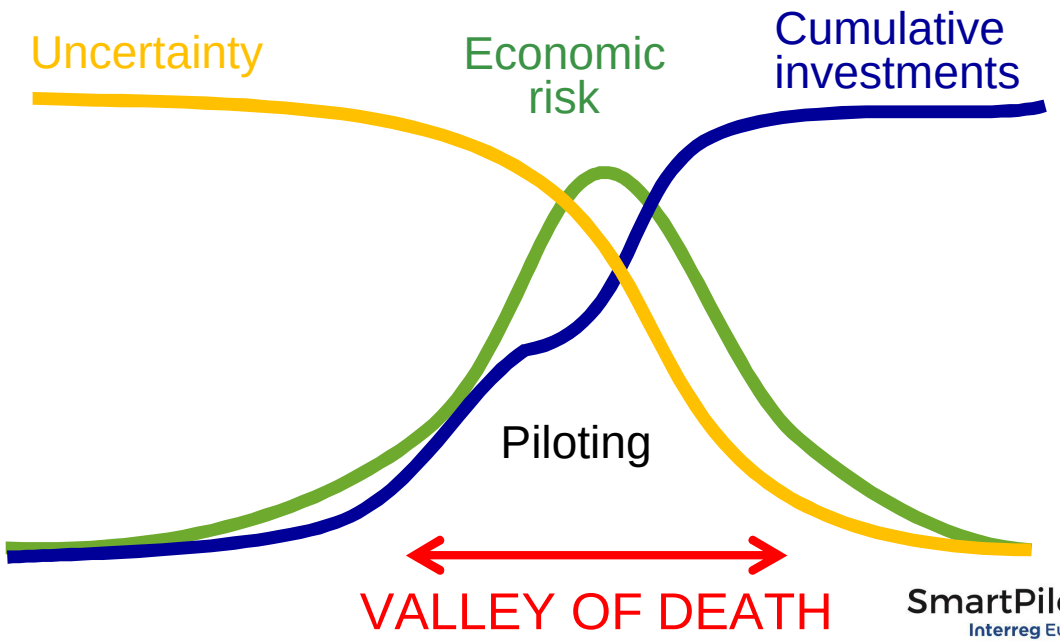
Efficiency, speed and lower risks to development with Shared Pilot Facilities



- In process industry early piloting is a key to speed up the development time for a new process or product.
- Piloting decreases the uncertainty for investment decisions.
- Open access Shared Pilot Facilities offer:
  - Competence in piloting and scale-up
  - Time saving with ready-to-use facilities
  - Cost savings by sharing the investment and operation costs

PILOT PRODUCTION

Combining product, manufacturing and market



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VTT pilot plants in bio and circular economy STATUS 5/2017

Key features for VTT pilots

- Covers the development chain from raw materials to end products.
- Two types of pilots: Process specific and multi-purpose.
- Scale up-of own technology development
- Main customers large companies
- SME:s varies by pilots, up to 50% of revenue
- Customer projects ~ 40%

Value for customers in bio and circular economy with VTT's extensive pilot infrastructure

Process chemistry

Green chemistry

Metals recovery

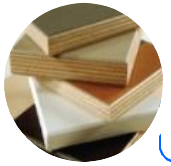
Thermochemical conversions

Gasification

Pyrolysis

Energy storage to chemicals

Fluidised bed combustion



Fibre and composite technology

Fibre based web production

Roll-to-Roll surface treatment

Polymeric materials processing

Cellulose fibre spinning

Food technology

Food and brewery

Industrial biotechnology

Fermentation and bioprocessing

High throughput robotics

Culture collection

Biomass deconstruction and fractionation

Biomass fractionation and pulping

Bioruukki Pilot Centre

Advanced analytical platform

Environmental engineering

Modelling and computational platform

Process modelling and concepts

Biomass and Waste Gasification Platform

Gasification Platform is used for gasification process development, testing of new feedstocks and for the development of gas cleaning technologies for different gasification applications

- Excellent know-how on fuel chemistry and gasification processes
- Unique fluidised bed gasification test facilities from laboratory to pilot scale
- Bench and pilot scale facilities for catalytic gas cleaning and hot filtration
- Fixed bed pressure gasification pilot
- Cutting-edge tools for techno-economic evaluations and process modelling (CFD, ASPEN)
- Track record on industrial development and demonstrations
- IPR on gasification and gas cleaning

Fast Pyrolysis Technology Platform

Fast pyrolysis test facilities are used for studying and developing next generation processes for producing liquid fuels and chemicals from biomass and waste streams

- Unique 0.5 tpd Pilot Unit suitable both for thermal and catalytic fast pyrolysis process development
- Complementary smaller semi-pilot scale units for fast and slow pyrolysis
- World class bio-oil chemistry know-how
- Cutting-edge tools for techno-economic evaluations and process modeling (ASPEN, CFD)
- Proven track record on industrial development and demonstrations
- IPR on fast pyrolysis technologies

Biomass processing semi-pilot

Our versatile facilities and skilled personnel enable effective development and scale-up of new biomass processing technologies and concepts.

- Feasible processing of biomass into valuable intermediates is **the crucial first step in ensuring the creation of new industrial value chains**.
- We offer development and scale-up of next generation **biorefinery concepts from TRL 1 to TRL 4** using
- A combination of relatively small multi-purpose semi-pilot scale reactors together with complementary processing devices **for chemical fractionation of biomass**
- A selection of grinders and refiners in laboratory and semi-pilot scale for **mechanical fractionation of biomass into fibrous and fibrillar particles** for fibre products.
- New growth area **Cellulose based fibres,** two different size pilot equioment

Process chemistry pilot plants

Our multi-purpose green chemistry pilot plants offer excellent facilities and skilled personnel for development and scale-up of new chemical processes and products.

- A combination of relatively large multi-purpose pilot scale reactors integrated to versatile downstream processing units.
- Scale-up and custom manufacturing services for many customers: from large international corporates to emerging domestic SMEs.
- Our key equipment:
  - Relatively large multi-purpose pressure reactors, up to 2 m^3 and 50 bar,
  - High solid content and dry processing tools
  - Versatile pilot-scale separation units,
  - Ex-classified equipment and pilot halls.

Fermentation and bioprocessing pilot

Comprehensive fermentation and down stream processing equipment and skilled people offer technologies from strain development to pilot scale production.

- Confirmation of biotechnical process performance in world-class fully equipped bio-manufacturing pilot plant up to 1.2 m^3 fermenter scale.
- Scale-up of bio-processes in batch, fed-batch and continuous cultivation with bacteria, yeasts or filamentous fungi.
- Production of batches for testing of DSP alternatives, pre-clinical API production, enzymes, antibodies, cosmetic ingredients.
- Piloting new bio-refinery concepts: optimized hydrolysis and fermentation, high dry matter processing, gas fermentation and equipment design.

Bioruukki Pilot Centre

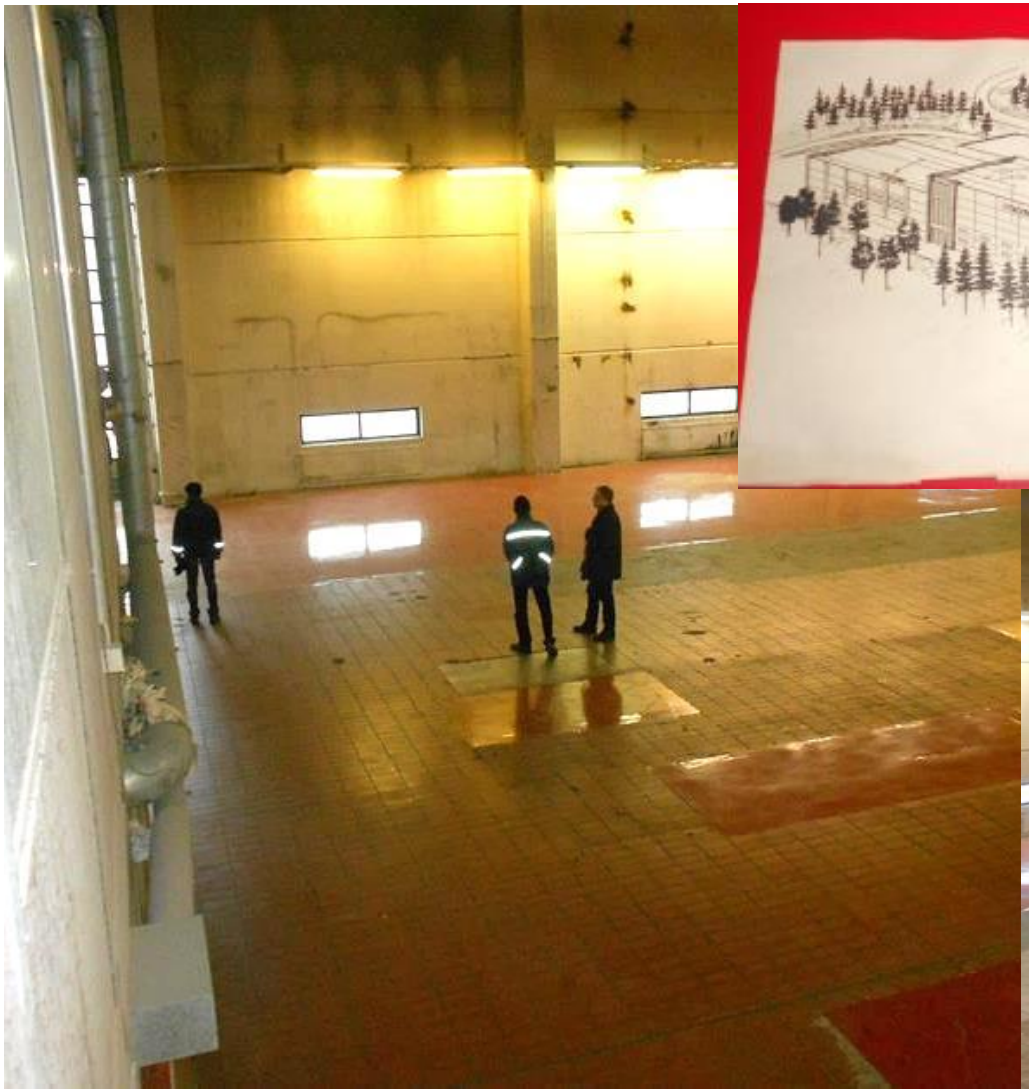
Bioruukki piloting ecosystem - efficiency, speed and lower risks to development with piloting and demonstrations

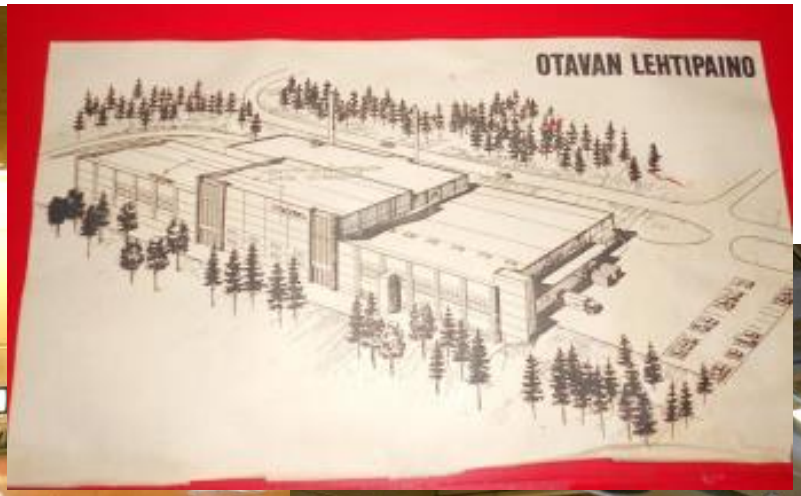
- **A new piloting ecosystem** for process industry scale-up and demonstrations.
- A former printing plant transformed to world scale R&D centre.
- Located close to Otaniemi campus.

BIORUUKKI IS THE LARGEST OPEN PILOT FACILITY IN BIOECONOMY IN NORTHERN EUROPE

Autumn 2011 Otaniemi – Construction of Metro station very close to the old pilot plants

The former printing hall at Bioruukki in 2013





Renovated pilot halls in 2014

Gasification hall

Pyrolysis hall

The first test run with the new Dual Fluidised Bed gasifier on 12.10.2015 was a success

Bioruukki pilot ecosystem – An integrated enabler to accelerate business in bio and circular economy

Biomass
Waste
Sidetreams

Thermochemical conversion

Biomass processing

Green Chemistry

Energy Storage

Fuels from waste
Recycled textile fibres
Chemicals from cellulose
Bio-oil from forest residues
Solar energy stored as liquid fuel
Design of new sustainable processes

Bioruukki Pilot Centre - Value from integration

1

THERMOCHEMICAL CONVERSION PLATFORM

Gasification and pyrolysis technologies for biofuels and biochemicals. Recycling concepts.

Full operation started Q3/2015

2

ENERGY STORAGE PLATFORM

Storage concepts for solar and wind energy through mono carbon gases to chemicals and materials

Starts at Bioruukki 2016

3

BIOMASS PROCESSING PLATFORM

Innovative biomass processing and cellulose fibres for new biobased value chains

Starts at Bioruukki 2017

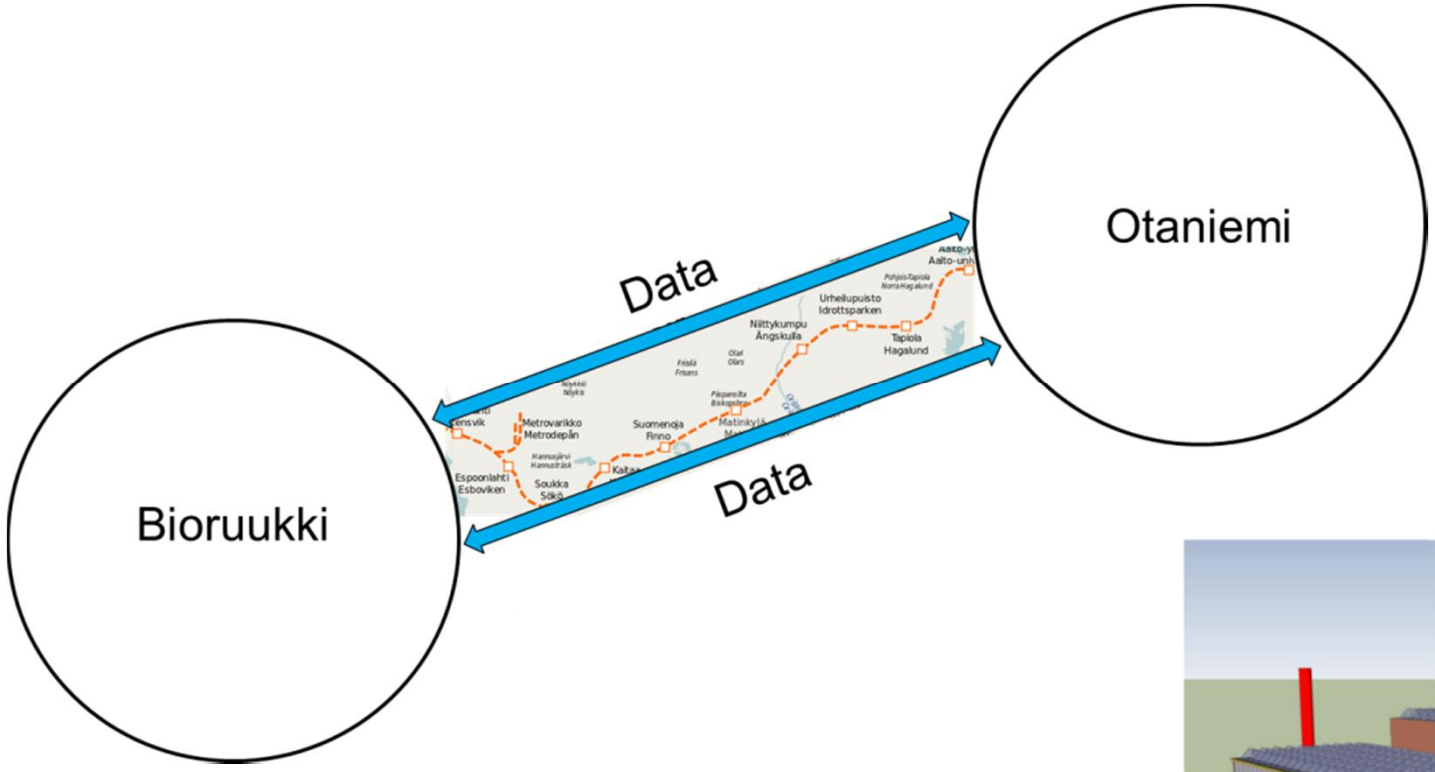
4

GREEN CHEMISTRY PLATFORM

Sustainable process chemistry and bioprocesses for biochemicals and tailored biobased hybrid materials

Starts at Bioruukki 2019

Future vision - Cleantech Garden ecosystem combining VTT Bioruukki, TransPower and partners



1 2 3 4 5 6 7 8

Bioruukki thermochemical platform started 2015

Opening ceremony 13.3.2015

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kaasutushalli_kamera1.mp4

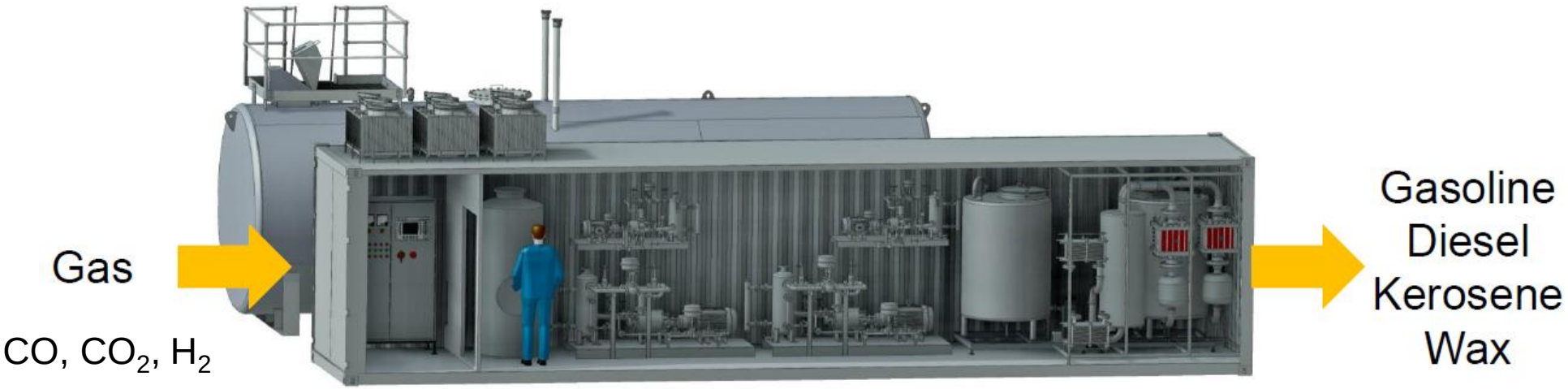
Gasification pilot plants

- DFB steam gasification pilot
- Bench-scale CFB gasifier
- Pressurized Fixed Bed gasifier

Pyrolysis pilot plants

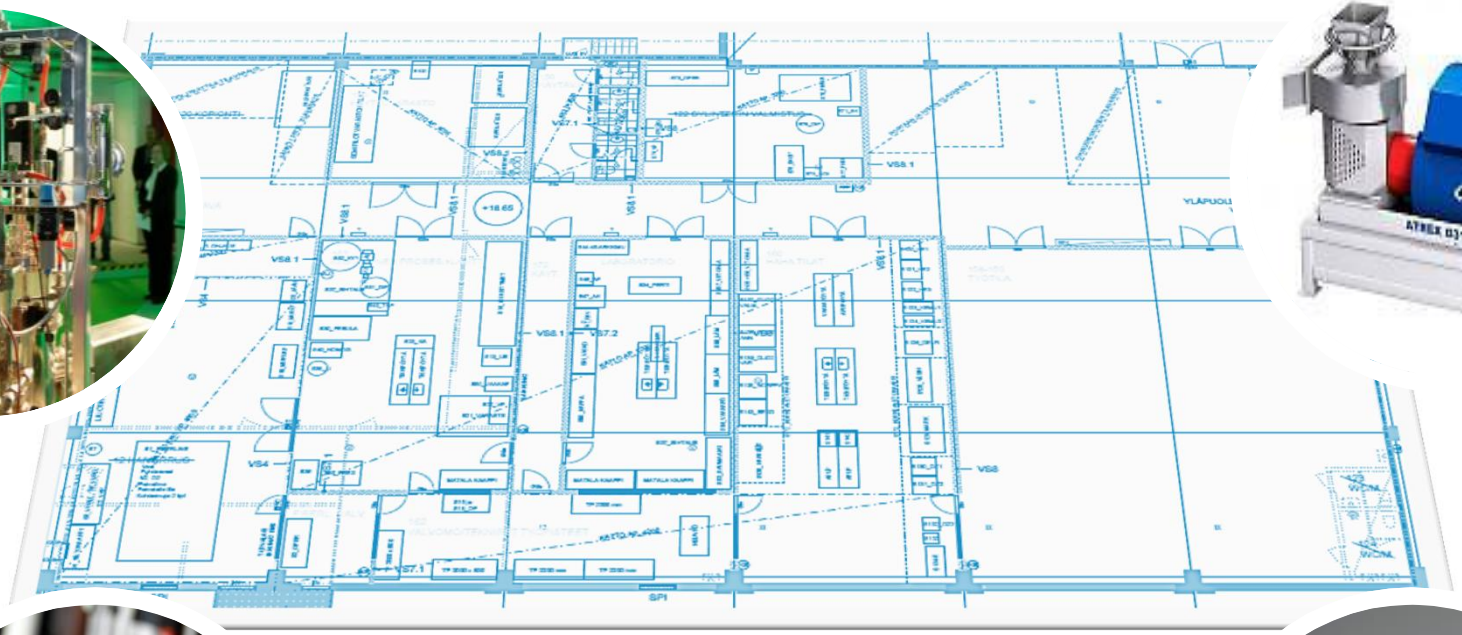
- Fast Pyrolysis CFB Pilot
- Fast Pyrolysis BFB Bench-Scale
- Slow Pyrolysis batch unit

Bioruukki Energy storage platform 2016



Biomass Centre to Bioruukki in 2017

Upgrading biomass processing



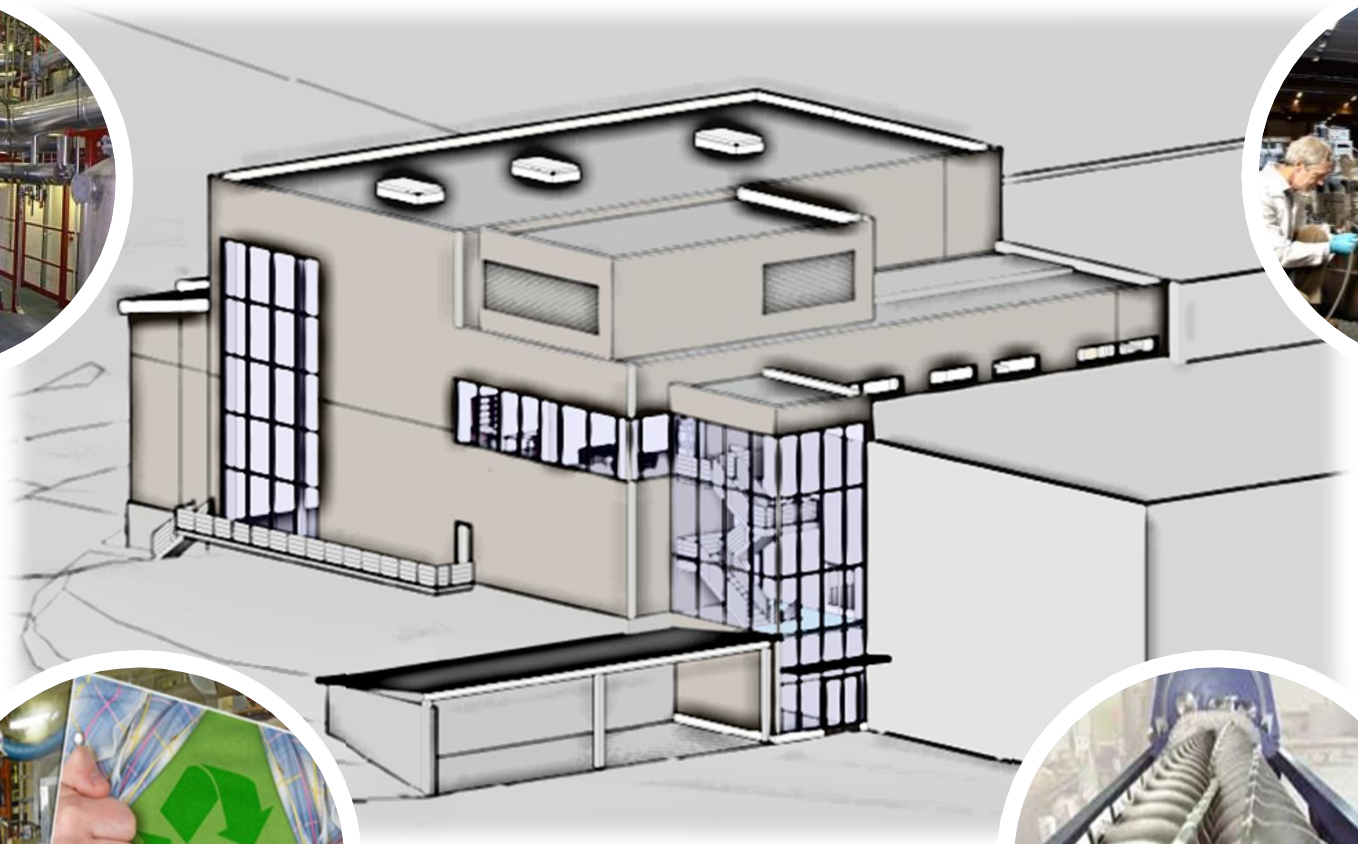
Fibrillated cellulose materials

Next generation fractionation of biomass

Cellulose fibre spinning platform

Green Chemistry Platform to Bioruukki in 2019

Multi-purpose pilot plant to serve industry and growing SME:s



Synergies of chemical and biotechnology pilot infra

New process concepts for recycling

New routes to biobased chemicals

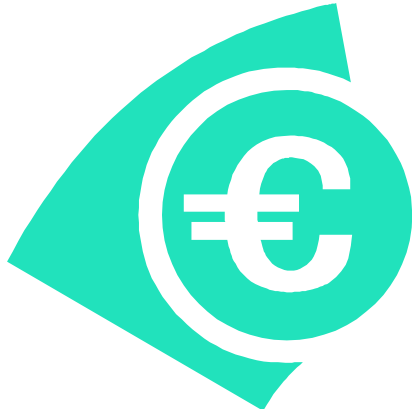
VTT Bioruukki operation and business models, Funding of the pilot investments and operations

VTT Pilot plant operation models

- VTT pilot plants are an integrated part of the research and innovation activities and infrastructure.
- No separate main organisation units.
  - Specialised personnel exists for running day shift principle
  - In case of special needs (e.g. 24/5 test runs) additional personnel from “lab” and leased employees are used.
- Equipment maintenance, modifications and construction done mainly by external workforce.
- VTT employees for Bioruukki related activities
  - Bioruukki pilot plant operations ~ 30 persons
  - Total at closely related research functions ~ 250 persons

VTT Bioruukki pilot plant Business models

- VTT pilot plants are not separate ”profit centres” or organisation units => separation of revenues of “pure piloting” is difficult.
- Typical revenue base for Bioruukki projects:
  - Jointly funded public research projects: ~ 65 %
  - Contract research or custom production: ~30 %
  - VTT self funded projects: ~5 %
- Revenue estimates for Bioruukki in 2017:
  - **Bioruukki related projects ~20 M€/a,**
  - Bioruukki “pure pilot operations” ~5 M€/a
  - All SONE “pure pilot operations” ~10 M€/a



- Projects acquired by research organisation, pilot experts and VTT Key Account managers.

Customer basis and R&D projects of Bioruukki

- Customers using Bioruukki Pilot Centre infra
  - 2013-2015: 137 customers, 186 projects, from 14 countries
  - Annually 40-60 companies
  - Annually SME's share of sales 7-10%
  - Annually clients from ~10 different countries
- Large companies bring the majority of contract research revenues
- Annually 10-15 SME's and start-up companies utilise Bioruukki infra in their development and scale-up work
  - E.g. partnering with start-up companies for piloting
- Annually about 20 public collaborative projects use Bioruukki infrastructure

Investment costs and funding of Bioruukki

- Estimated total costs by 2019 are 32 M€
  - Thermochemical platform 14 M€.
  - Biomass Processing platform 8 M€
  - Green Chemistry platform (cost estimate) 10 M€
- Financing from three main sources:
  - Special grants from national government budgets: 13 M€
  - Owner of the estate (paid in rents): 9 M€
  - VTT's own capital investments: 10 M€
- Own labour costs for construction and start-up phases
  - VTT own funding (~1 M€) and public R&D projects
  - ERDF funding 0,5 M€, start-up of the fibre spinning pilot
- Other operations in business unit SONE share the depreciation and rental costs of pilots.

Impact and co-operation

Scale-up and demonstrations for companies
- Flexible research and piloting infrastructure
- Strong competence pool and expertise
- Small scale manufacturing for SMEs

International innovation ecosystem for research partners
- Large networks in Europe and globally, partner in key European piloting networks
- Active player in H2020 initiatives and projects

In Espoo, close to Otaniemi innovation hub
- Whole VTT expert and competence pool close
- Joint Aalto-VTT Bioeconomy Infrastructure with Academy of Finland status (FIRI)

Active partner in national bioeconomy
- Supports national targets
- Connects national players in bioeconomy
- Wide collaboration in Finland

BIORUUKKI PILOT CENTRE:

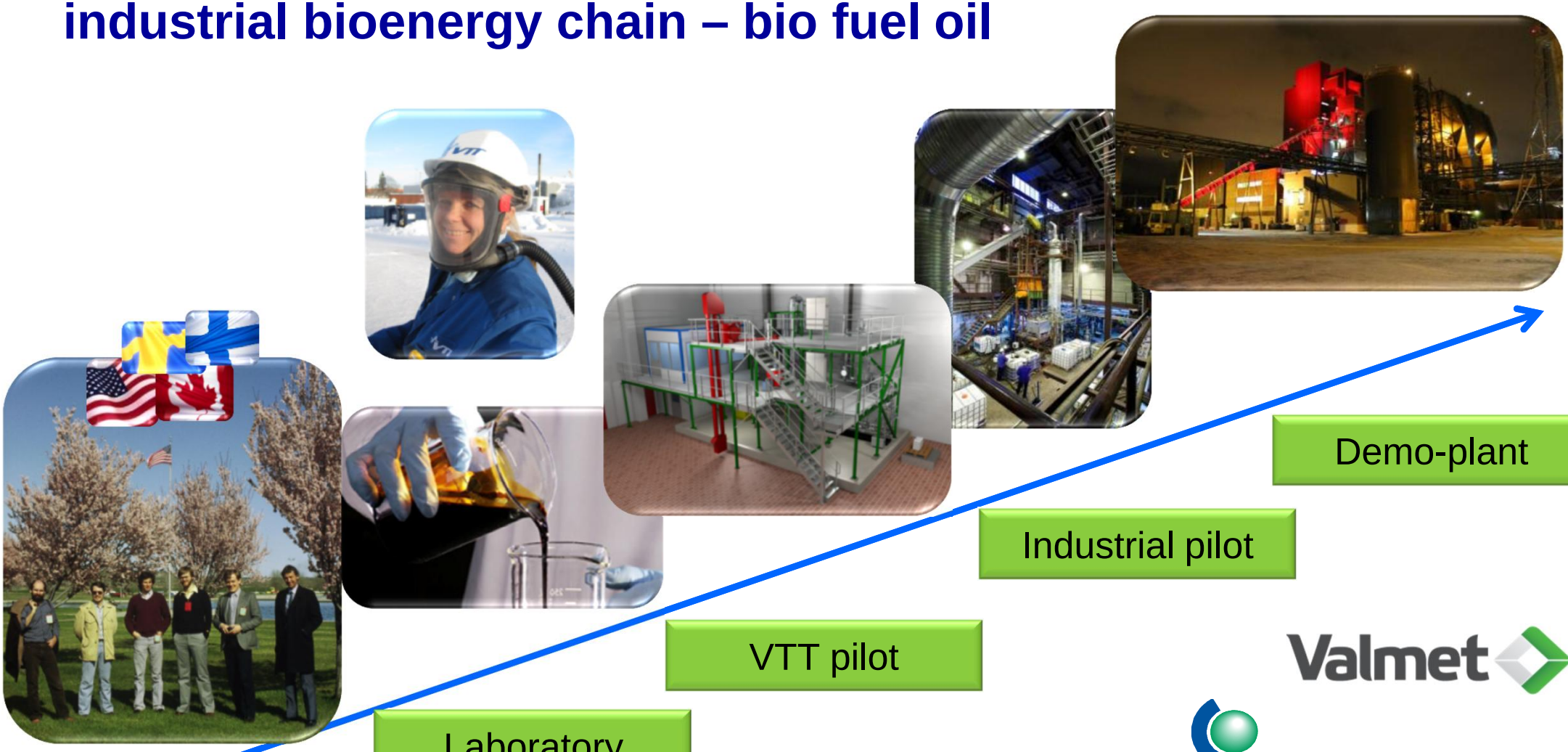
National asset

International environment

Global competence

Piloting results are utilised broadly in Finland *(examples):*
- *Fortum: Joensuu bio-oil plant*
- *Chemigate: New production plant for starch based paper chemicals in Lapua*
- *Fazer: Beta-glucan production at Lahden kauramylly*
- *Metsä Group: Äänekoski bioproduct mill*
- *Start-up companies: Spinnova (Jyväskylä), Paptic (Espoo)*

New industrial technologies: VTT experimental resources for a whole industrial bioenergy chain – bio fuel oil



Valmet

Fortum

UPM

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SME support in scale-up:
New cost effective industrial process for starch modification

- Pilot scale development of production recipes
- Process scale-up and chemistry expertise
- Material production for application testing

"VTT's flexibility and ability to deliver skilled research and scale-up testing at the pilot plant have proven invaluable."

Seppo Lamminmäki
CEO, Chemigate Oy

Chemigate

New flexible piloting platforms: Cellulose based textile fibre demonstration platform to Bioruukki Pilot Centre in Q2/2017

Fibre spinning pilot line

- Cellulose based fibre spinninh
- Recycled raw material pre-treatment
- Cellulose dissolution and filtering units
- Cellulose carbamate production

Suitable material for textile fibre and clothing demonstrations

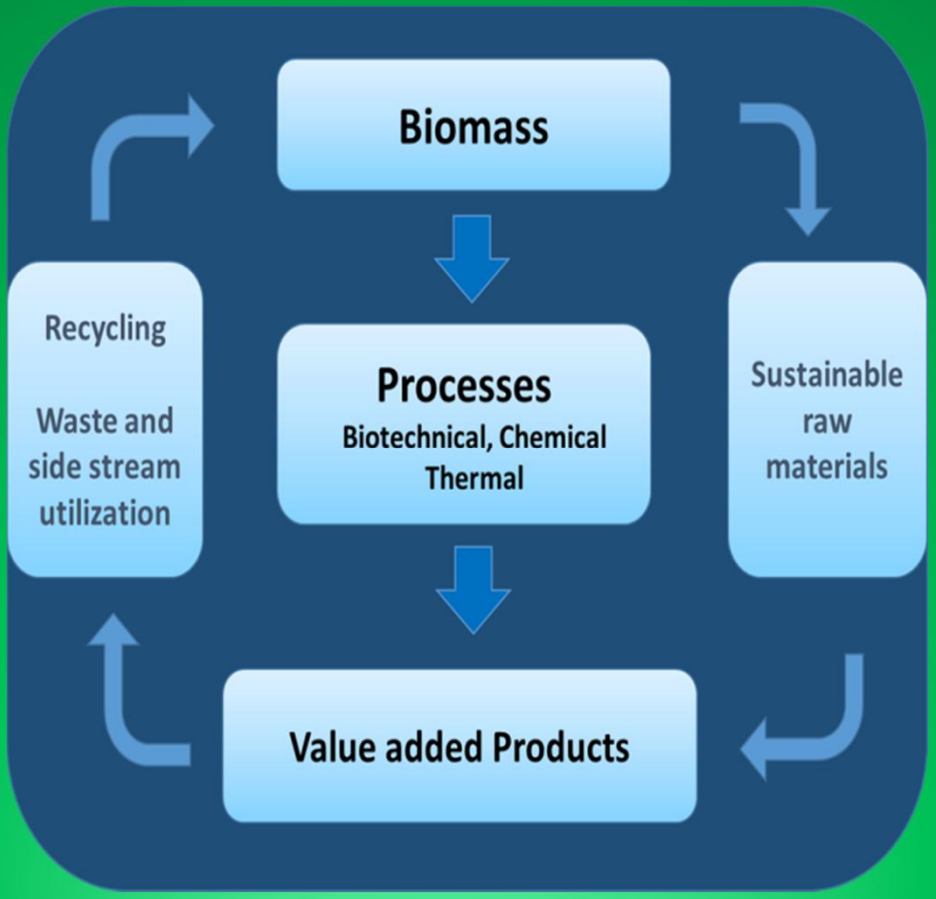
- Recycled or virgin raw material
- Stable fibre web production and post treatment units

Aalto-VTT Bioeconomy Infrastructure:
Global Competence in Wood & Non-Food Biomass Refining

Impact

- Scientific excellence
- Educating skilled professionals
- Innovations through enabling technologies
- Entrepreneurship
- Design

BIOECONOMY infrastructure



Collaboration

- National and international research organizations
- Companies
- EIT Climate KIC
- ESFRI 2020

HELSINGIN YLIOPISTO

LUT Lappeenranta University of Technology

Luke LUONNONVARAKESKUS

Åbo Akademi

eit RawMaterials

Bioruukki Pilot Centre is part of “European champions league of bioeconomy pilots”

European pilot collaboration projects with active participation of VTT and Bioruukki

ERIFORE

- Horizon 2020 roadmap project for forest based circular bioeconomy research infra development and collaboration
- Coordinated by VTT

SmartPilots

- Interreg Europe project for bioeconomy pilot cooperation, business models and political influencing

EU-Great

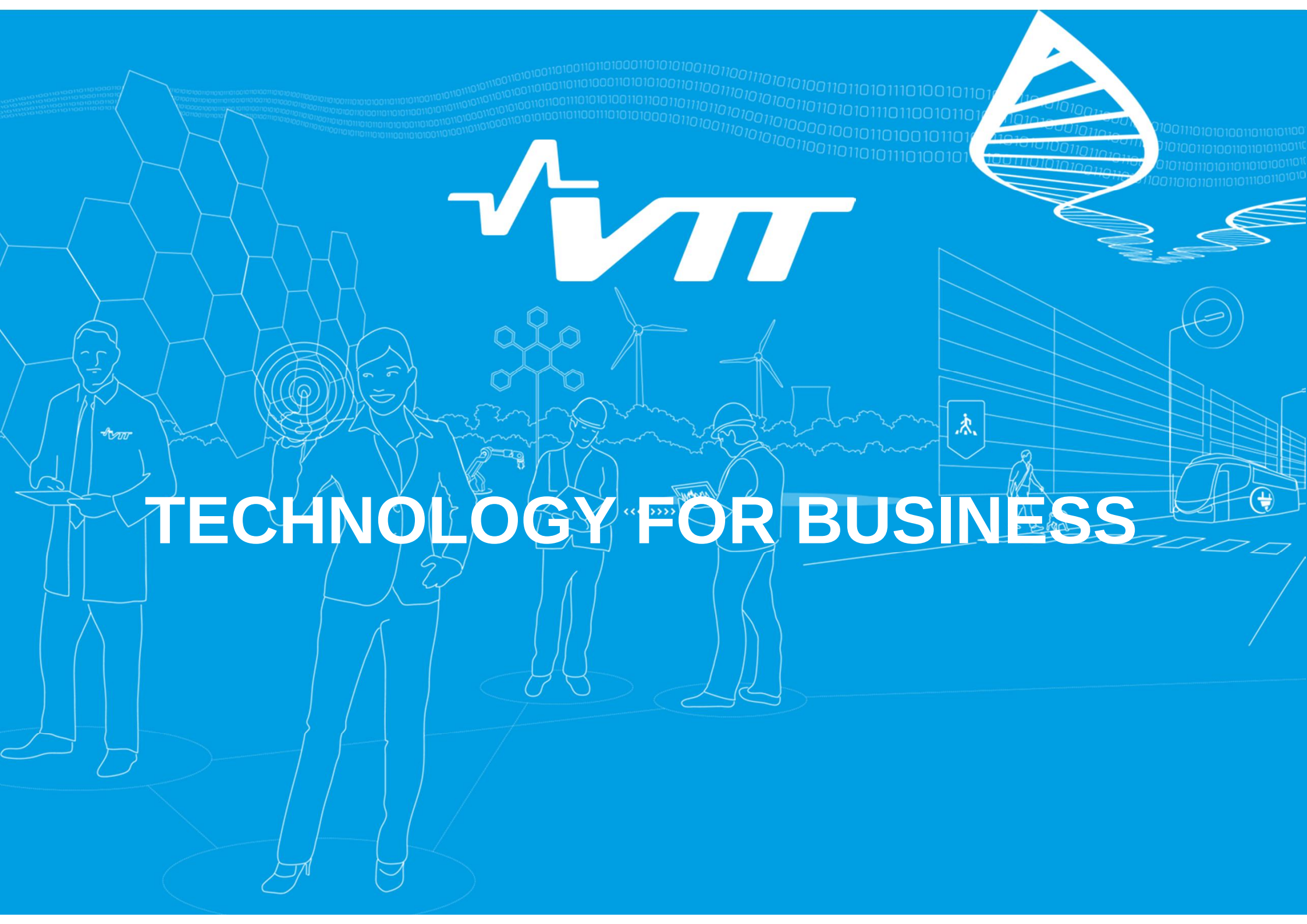
- Exploring the best practices and barriers for research infrastructure funding (H2020)

Pilots4U

- Combines open access pilots in industrial biotechnology, chemistry and bioenergy.
- Assessing capabilities for industry driven development projects

Bioruukki piloting centre and VTT – a facility for visionary innovation

TOGETHER WITH OUR PARTNERS!


TECHNOLOGY FOR BUSINESS